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CONTENTS.

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TECHNICAL EDUCATION IN RELATION TO INDUSTRIAL DEVELOPMENT.[1]

THE industrial development of the United States has created a demand for men with a technical education. The presence in the community of men with a technical education contributes to the more rapid development of our industrial enterprises. Each factor is at once a cause and a result and neither could be most effective without the other.

The history of industrial development and of industrial education are naturally inseparable. They must be treated together if one would understand their interdependence. It was never intended by the mother country that her New England colony should ever engage in manufacturing. The Earl of Chatham once said that the

Colonists had no right to manufacture so much as a single horse shoe nail.

In 1750 a law was passed by parliament which prohibited the 'erection or continuance of any mill or other engine for slitting or rolling iron, or any plating forge to work with a tilthammer, or any furnace for making steel in the colonies under penalty of two hundred pounds.' Every such mill, engine, forge or furnace was declared a common nuisance which the governors of the province were bound to abate. The real cause of the revolution is to be found in the discontent of the colonies with such legislative oppression.

The war of the revolution, stopping all

[1] Commencement address, June 14, 1906, at the Worcester Polytechnic Institute, by Mr. Charles G. Washburn, president of the corporation.

imports from Great Britain, revived such domestic industries as had formerly existed.

Upon the return of peace in 1783, the influx of foreign goods threatened our manufacturing industries with ruin. The revolution had been successful, but had failed of its ultimate purpose. The establishment of a national government was essential to the maintenance of manufactures, the division of the powers of government among thirteen sovereign states made a uniform revenue system impossible. The manufacturers, mechanics and tradespeople wanted a federal constitution and their influence compelled its adoption by Massachusetts. The event was celebrated by processions all over the country and on one of the banners in Philadelphia was inscribed the motto:

> May the union government protect the manufacturers of America.

The first Congress justified this hope by imposing duties which should protect manufacturing enterprises, which may be considered as the result partly of the revenue laws of 1789, partly of the embargo in 1807, and of the restrictive measures and of the war of 1812 that followed. How little the idea that we should ever become a great manufacturing nation was held by our people may be gathered from correspondence between Benjamin Franklin and John Adams in 1780, in which Franklin said:

> America will not make manufactures enough for her own consumption this thousand years.

and Adams replied:

> The principal interest of America for many centuries to come will be landed and our chief occupation agriculture. Manufactures and commerce will be but secondary objects and always subservient to the other.

The feeling of skepticism in regard to the introduction of mechanical and other improvements was not confined to this country.

Admiral Sir Charles Napier fiercely opposed the introduction of steam power into the royal navy, and one day exclaimed in the House of Commons,

> Mr. Speaker, when we enter her Majesty's naval service and face the chances of war, we go prepared to be hacked in pieces by cutlasses, to be riddled with bullets, or to be blown to bits by shots and shell; but Mr. Speaker, we do not go prepared to be boiled alive.

Yet in a few years Sir Charles Napier found himself in command of the largest steam navy that the world had ever seen.

George Stephenson, the eminent engineer, spoke of the probability of steamships crossing the Atlantic. 'Good heavens! what do you say?' exclaimed Lord Stanley, rising from his seat. 'If steamships cross the Atlantic I will eat the boiler of the first boat.'

In more recent years a lord chancellor, even after he had seen a theater illuminated without candle or oil, poured ridicule on a scheme for 'supplying every house in London with gas in the same manner as they are now supplied with water by the New River Co.' Again, so eminent a chemist and gas specialist as Sir Humphry Davy himself is alleged to have said on one occasion that it was as reasonable to talk of ventilating London with windmills as of lighting it with gas.

The Academy of Sciences in France when consulted by Napoleon at the beginning of the century as to the steamboat spoke of it as a 'mad idea, a gross error, an absurdity.' When Fulton's first steamboat made the trip from New York to Albany in 1807, it happened to be the seventeenth of August, which caused many preachers to curse the machine, on the ground that seventeen was the total of the horns and the seven heads of the beast of the Apocalypse.

It was not until after 1830 that our manufactures developed, for it was not until 1835 that the construction of our

railways was vigorously commenced or that steam was availed of to any considerable extent for motive power. Meantime and from the first the cause of education had never been neglected in New England. In 1636 the general court of Massachusetts Bay, which met in September of that year, appropriated £400 towards a 'school or college,' and in 1638 John Harvard left half of his property, amounting to about £780, and all of his books, about 300 volumes, to the institution which thereafter was known as Harvard College.

For many years, indeed as late as 1850, the common school, the academies, high schools and colleges were the only instrumentalities of education in this country.

But it must not be thought that the need for a different training had not been early recognized. It was pointed out as early as 1830 that instruction in natural science could only be found in the colleges which were designed to educate those who were intended for the professional life of the ministry, the bar and medicine, and regret was expressed that no educational training had been provided for those who proposed to occupy themselves with practical affairs, and it was pointed out that those who had signalized themselves by making great inventions had been self-educated men. The inventive faculty of our people had already been at work. John Fitch, Oliver Evans and Robert Fulton had long since demonstrated that steam was to be the great motive force for land and water vehicles.

Amos Whittemore had produced the carding machine; Eli Whitney, a Worcester County boy, had invented the cotton gin. Thomas Blanchard, of Millbury, had invented, among many other ingenious and useful devices, a lathe for turning irregular shapes. Erastus Bigelow, born in West Boylston, invented, before he was fourteen, a hand loom and machine for making piping cords, and the first power loom for making counterpanes, coach lace, Brussels and Wilton carpets and wire cloth, and laid the foundation of the prosperity of the neighboring town of Clinton.

Elias Howe, of Spencer, invented the sewing machine, and Morse had invented the electric telegraph.

In view of all these and scores of other inventions, it is not surprising that the attention of thoughtful men was directed to the fact that the development of our industrial enterprises was a matter of prime importance to the prosperity of the country, and that some special training should be provided for those who were to engage in such occupations. It is true that under the patronage of our colleges, scientific schools had been established through the generosity of private individuals. Abbot Lawrence, of Boston, founded the Lawrence Scientific School of Cambridge in 1848. Joseph E. Sheffield, of New Haven, endowed the Sheffield Scientific School of Yale in 1847, and Abiel Chandler, of Walpole, N. H., endowed a separate department of technology at Dartmouth in 1852. These schools, however, all taught pure science. It was left for the polytechnic school as later developed to teach applied science. Such, in a general way, were the conditions in 1860.

July 2, 1862, Congress passed a bill granting to each state 30,000 acres of land for each senator and representative in Congress for the purpose of endowing institutions for teaching such branches of learning as are related to agriculture and the mechanic arts, and this, too, at a time when the failure of the peninsular campaign against Richmond had left the people of the country in a state of deep depression. This gave a great impetus to the cause of technical education.

The Massachusetts Institute of Technology was opened to students in 1865.

The foundation of our own school came about in this way. In the year 1865 John Boynton, of Templeton, in this state and county, placed in the hands of his former partner, David Whitcomb, of Worcester, the sum of one hundred thousand dollars for the endowment of a free school, which was to be located in Worcester if the citizens of Worcester should provide the land and suitable buildings. This condition was complied with by a gift of the land and of $61,111 contributed by two hundred and thirty-two individual names and from twenty shops and factories. The institute was incorporated May 9, 1865, under the descriptive and perhaps prolix title of Worcester County Free Institute of Industrial Science, which was changed in 1887 to the name which the institute now bears.

December 2, 1865, Ichabod Washburn, of Worcester, offered to establish a machine shop as one of the departments of instruction of the institute.

The selection of the location of the school was an appropriate one. Worcester, then a city of 30,000, had long been famed for her industries and for the intelligence and public spirit of her citizens. Her industrial growth had taken place since 1830, prior to which time her manufactures had been of the most primitive sort. The Rev. Edward Everett Hale, whose life work, happily not yet concluded, has been so productive of good to his fellow-men, told me that Judge Merrick, a resident of Worcester, once met Samuel Slater, the pioneer cotton manufacturer, on the street in Worcester. Judge Merrick said to Mr. Slater:

> We shall never be a manufacturing town in Worcester because we have so little water power.

Mr. Slater said in reply:

> Judge Merrick, you may live to see the time when Worcester will need all the water of Mill Brook to provide the steam for her steam engines.

This conversation must have occurred at some time prior to 1835 and perhaps about 1830.

It is difficult to realize that William A. Wheeler, of Worcester, who is credited with having installed in 1825 the first steam engine in the state west of Boston, should have discarded it and used horse power until 1840, when he put in another engine. William T. Merrifield at the same time put in an engine of from four to six horse power. These were probably the first efficient steam engines in Worcester.

An indication that this was congenial soil in which to plant an institution like ours is found in the formation of the Mechanics' Association, first attempted in 1819, and successful in 1841. The object of the association was:

> The moral, intellectual and social improvement of its members, the perfection of the mechanic arts, and the pecuniary assistance of the needy.

Another object was the holding of an annual fair for the exhibition of the mechanical products of the city, and the first fair was held in September, 1848.

In July, 1854, in commenting upon the association and its work, the statement was made that:

> Notwithstanding the inadequate supply of water power which is everywhere deemed so essential for the successful development of the mechanic arts, without the aid of a single act of incorporation, mechanical business has increased in this city by individual enterprise alone more than tenfold.
>
> The mechanics as a class are more enlightened than formerly, their course is onward and upward; they are not only increased in numbers, but continually expanding in influence and usefulness.

Ichabod Washburn was very much interested in this association, and eight or ten years before the founding of the institute had discussed with the Rev. Dr. Sweetser the feasibility of establishing a school in connection with the Mechanics' Association for giving scientific instruction to mechanics in the fundamental principles of me-

chanics and chemistry. It was expected that funds for the enterprise would be contributed by the prosperous mechanics and manufacturers of Worcester. The financial panic of 1857 prevented the execution of this plan, and Mr. Washburn later decided to carry out his earlier conceived purpose in connection with the institute.

Fortunate, thus in its foundation and its location, the institute began its life under the happiest auspices. In one particular its scheme for education was unique in combining with the studies ordinarily pursued in technical schools, manual labor in a shop, run upon a commercial scale and producing articles to be sold in the market. Unsuccessful experiments in thus combining the practical with the theoretical had previously been made in Germany and Austria.

At this point I am led to inquire just what sort of a school this was in 1865, and what its founders expected of it. I understand that in the definition of the present day a trade school aims to give the pupil a thorough, practical knowledge of some handicraft. In the manual training school instruction is given in various kinds of work with tools for educational discipline. In the technical or engineering school the sciences are taught in their practical application to the various industries.

Mr. Boynton, in his letter of gift which was prepared under the advice of the Rev. Seth Sweetser, of Worcester, and Judge Emory Washburn, of Cambridge, adopted in most comprehensive form the curriculum of the scientific school as then known, with the addition of some subjects not ordinarily included.

Mr. Washburn's final letter of gift and instruction, dated March 6, 1866, discloses a purpose to establish a trade school as we now understand it, excepting that in addition to learning a trade the apprentice was to be instructed in the principles of science.

Dr. Charles O. Thompson, the first president of the faculty, of brilliant accomplishments and magnetic personality, in his inaugural address delivered at the institute November 11, 1868, said, among other things:

Add to these considerations the fact that boys whose faculties are kept constantly alert by the training of the school are in a condition to learn faster than others the practical application of science and that the time spent in the shop will serve the double purpose of instruction and physical exercises and it will be admitted that this form of a manual labor school is at least an experiment worth trying.

The late Senator George F. Hoar, one of the charter members of the board of trustees, always untiring in his efforts in behalf of the institute, and whose memory should always be held in most grateful remembrance by us, in addressing a committee of the Massachusetts Legislature, February 11, 1869, urging an appropriation of $50,-000, said, among other things:

You can not find an instance of a boy who has been educated in the Scientific School at Harvard College going back to the bench of the workman or the farm, and so of the Institute of Technology. Theirs will be a different, and in many particulars a higher education than ours. * * * You will not find there any boys who, having studied for two or three years, are going back to work in the shop * * * and there they will work their way up from the journeyman to the foreman and then the master mechanic.

All this testimony leads, I think, to the conclusion that the institute in 1865 was what would now be considered a combination of a scientific school and a trade school, and of a grade not as high in some respects as either the Scientific School at Harvard or the Institute of Technology in Boston.

It was frankly admitted that it was an experiment, and attention was called at the time to the fact that at Berlin the workshop connected with the school had been tried and abandoned twice. But the experiment

succeeded here, and the combination has now taken the permanent form of an engineering school of the first rank, peculiar in this respect, in which we believe it to be superior to all others, that the practise not only illustrates the scientific principles taught in the school, but also gives the students considerable experience in the use of tools and a practical knowledge of the workings of a commercial shop.

Since the founding of the institute, technical schools have been springing into existence with great rapidity in response to a constantly increasing demand for trained engineers. In speaking of this fact, President Eliot said in 1905:

> It is also true that separate schools have been set up in many parts of the country to train young men for the technical and scientific professions, but in time these schools are likely to be transferred to neighboring universities or to content themselves with training men for the lower grades of these professions, the universities all over the country being sure to appropriate the training of young men for the higher walks of the scientific professions and of business. * * * It is obvious that the policy of the American universities now under consideration has had, and is going to have, a strong effect to uplift the relatively new professions, like those of engineering, applied chemistry, architecture, music, mining, forestry, the public service and large scale manufacturing. These are highly intellectual occupations not yet universally recognized as on a level with divinity, law and medicine. The American universities will in a few generations put them all in their higher grades absolutely on a level with the older callings.

This is an interesting prophecy, but so far as it relates to the absorption of existing independent technical schools by the universities is not likely to be immediately fulfilled.

That the Worcester Polytechnic should have developed into an engineering school is a cause of great satisfaction. Progress and growth characterize all successful educational institutions. Listen to this statement:

> After God had carried us safe to New England and we had builded our houses, provided necessaries for our livelihood, reared convenient places for God's worship and settled the civil government, one of the next things we longed for and looked after was to advance learning and perpetuate it to posterity, dreading to leave an illiterate ministry to the churches when the present ministers shall be in the dust.

Such was the modest purpose of the founders of Harvard College. If the founders of this school should have the power to see us, as perhaps they have, how small their surprise compared with that of the fathers who behold Harvard University with an endowment of $18,000,000, and a student body of 4,000 being trained for most of the occupations, professional and industrial, necessary to the progress and prosperity of the nation. Contrast the first graduating class of seven with the last commencement, when 1,073 degrees were conferred. Compare the sphere of usefulness of the first president of Harvard with that of the distinguished educator who now occupies that position and who is sought to take part in the discussion of the rights of capital and labor, the proper management of corporations and kindred practical questions, to the great profit of his countrymen.

During a period of thirty years there has been a steady development in all of the departments of the institute, and the enlargement and the enrichment of the various courses has kept pace with rapidly increasing demands.

In the field of mechanical engineering this development has usually been in response to some special requirement.

The demands for power for the generation of electricity and for marine work have led to the present efficient and well-developed high-pressure steam boilers and engines, together with all the auxiliary power-house apparatus. This has also resulted in the perfecting of the steam turbine for commercial purposes, while cheap-

er power has been provided by the gas engines and producers, and, with the aid of electrical transmission, water power is also the basis of great power plants. Large wheels, higher speeds, better regulation and more efficient results are some of the new requirements which are being met in hydraulic work.

The problems in connection with the handling and transportation of materials have made great demands on the mechanical engineer and have resulted in improved hoisting machinery, conveyors, cranes, elevators, larger and more efficient locomotives and cars.

On the manufacturing side the demands have been fully as great, competition requiring more rapid and economical methods of production. These have been met by better and more powerful machine tools, automatic machinery, jigs and interchangeable parts, and within the last few years the introduction of high-speed steels for rapid work and surface grinding. Rolling-mill machinery has kept pace with the requirements for structural steel, while the response to the calls for strong and light parts for the bicycle and automobile has made possible the present perfection of these machines. The rapid development of machine molding in the foundry has come from the demand for cheaper and better castings. The further reduction of factory costs has led to the study of shop management, where every movement of worker and material is considered with an idea of reducing the cost of production.

While there have been no startling discoveries along mechanical engineering lines, there has been a continual evolution toward greater and more efficient production of power and of commercial products.

As illustrations of practical results attained may be mentioned the fact that an indicated horse-power can be produced to-day with one third the coal consumption of thirty years ago.

While in the important art of wire rod rolling, in the development of which the oldest and a most highly respected member of our board of trustees and graduates from this school have had a very conspicuous part, the tonnage output has been increased twentyfold and the cost per ton for rolling has been greatly reduced. In the year in which the first board of trustees was organized, wire manufacturers in Worcester were importing Swedish iron billets which were rolled in South Boston at a cost of $1 per 100 pounds. To-day steel billets can be rolled for 12½ cents per 100 pounds.

In the department of civil engineering the training in 1870 was confined to pure mathematics, surveying and a very limited application of theory to practise; what would now be regarded as rudimentary.

To-day the student must receive a thorough training in mathematics, physics, theoretic and applied mechanics; he must be well grounded in the elements of chemistry; and familiar with all the principles of bridge construction, and the framing of great buildings; he must possess intimate knowledge of materials, stone, brick, cements, mortars, concrete and reinforced concrete; he must know what has been done and is being done in actual construction in the several lines of his profession. And that he may be fitted to eventually direct large undertakings, he must be familiar with the principles of power development and transmission in all its modern forms.

The work of the civil engineer of to-day consists largely in the design, construction and maintenance of fixed structures. Streets, bridges, water supply systems, sewers, conduits, subways, elevated tramways, docks and wharfs in our cities; embankments, deep cuts, bridging, tunnels and

terminals for the railroad systems; dams, reservoirs, canals, penstocks, powerhouses for the great hydraulic developments, and for the reclaiming of the arid lands; ship canals, locks and dry docks for shipping; steel frames, foundations for the modern skyscraper; these are some of the subjects which occupy the attention of the civil engineer to-day.

The magnitude of these works, their cost, and the rapidity with which they must be designed and built, have enormously increased in the past thirty years. A more exact knowledge of the properties of all kinds of structural material and of the laws which govern the forces of nature, with which the engineer must work, are demanded for the economical treatment of these large projects. The percentage of error and the factor of ignorance must be reduced to the lowest terms.

In physics many important discoveries have been made. Prominent among them has been the establishment of the theory that light consists of electric and magnetic vibrations.

The discovery of electromagnetic waves which led to the invention of wireless telegraphy, by which means within a few weeks a message has been sent across the ocean.

Discoveries regarding the connection between the all-pervading ether and matter.

The discovery of the peculiarities of the discharge of electricity through gases which led to the discovery of X-rays.

The liquefaction of air and gases which led to discoveries regarding the properties of bodies at very low temperatures.

The discovery of radium and other radioactive bodies and the investigation of their properties which has produced profound changes in our views regarding the construction of matter.

Discoveries of the process of conduction of electricity through gases, liquids and solids.

Developments in electrical engineering have been almost spectacular in their number and importance, revolutionizing, as they have, means of transportation and for the transmission of speech and power, and for lighting.

The telephone in 1876. The incandescent lamp in 1879. The commercial development of dynamo machinery and electric motors. The commercial application of electricity to street railway work, which had its beginning less than twenty years ago. The transmission of power over great distances made possible by the development of the alternating current transformer. A catalogue of discoveries and inventions in this field is not necessary, as one sees them on every hand. It may be truthfully said that the department of electrical engineering has been created within a comparatively few years. It was not until 1896 that our department of electrical engineering was separated from the department of physics within which it had its beginning. Now it is one of our great departments, attracting large numbers of students.

In 1868 the demand for trained chemists in this country was very small. At that time even the iron and steel industries did not perceive the advantage of controlling their various processes by careful and accurate analyses.

Andrew Carnegie was the first steel manufacturer who saw the importance of having trained chemists in his works, and in a short address made several years ago he said that one important cause contributing largely to his success was this fact. Such being the case, there was, at the time the institute was opened, little inducement for students to take up the subject of chemistry with the idea of following it as a profession, and though in the first catalogue issued the courses of study announced were mechanical engineering, civil engineering

and chemistry, the only difference in the work of the mechanical engineering department and the chemical department was that the time devoted to shop practise by students in mechanical engineering was spent in the chemical laboratory by those who had taken up the chemical course, and the time in the chemical laboratory was devoted entirely to analytical work. Such important subjects as organic chemistry, industrial chemistry and physical chemistry received no attention. All the work of the department was done in one room, which was also used for the little laboratory work that was given to the students in other courses.

As an illustration of the slight demand there was for chemists, the catalogues show that in the first six classes that graduated from the institute there is only one graduate who followed in after years the profession of chemistry.

Starting in 1868 with only one instructor in chemistry, and only one room for the laboratory, the department of chemistry, at the present time, 1906, has six instructors and separate laboratories for general chemistry, analytical chemistry, organic chemistry, industrial chemistry, sanitary chemistry and biological chemistry.

The work of the department has increased in a like manner. Where in 1868 instruction was only given in two main subjects, general and analytical chemistry, instruction is now given in fourteen different branches of chemistry. The cause of this increase, besides the increase demanded by the growth of the institute, is due to the difference in the positions now opened to chemists. In the early years of the institute the position offered to the graduate from the chemical department were practically that of the analyst, one who could make an examination of iron and steel. No knowledge of organic chemistry, or physical chemistry, or industrial chemistry, or sanitary chemistry was expected and electrochemistry was an unknown science. If the graduate from the chemical department could make a chemical analysis, that was all that was demanded or desired. To-day, this is very different, for the positions offered to chemists require at least a fundamental knowledge of the various branches of chemistry, and one who is only fitted for an analyst has very little prospect of ever rising to any prominent or satisfactory position. This is due to the fact that there is hardly a large manufacturing company that does not now require a chemist, not merely to make analyses, but for the study and the improvement of processes.

Sanitary science in all its branches, agricultural chemistry and electrochemistry all demand chemists, and in every one of these branches will be found men trained in chemistry at the institute.

America is also beginning to follow the German plan, namely, to have connected with the most important manufacturing processes a research laboratory where chemists are employed in strictly research work, not with the work that is being done day by day in the factory, but on problems that, starting from theoretical ideas, may be tested to prove their commercial worth.

An interesting statement in a recent address by James M. Dodge, then president of the American Society of Mechanical Engineers, which is confirmed by the experience of our own graduates, reveals the fact that the average annual salary of the technical trained man is over $2,150, and for the nontechnical, but trade trained man, $790, so that the gain in average annual income due to a technical training is over $1,360. This amount capitalized at 4 per cent. gives to a man receiving a technical training a potential increase in value of $34,000. There are over one thousand liv-

ing graduates of the institute, to make no mention of an equal number who have spent more or less time at the institute, but who have not taken a degree, so that at the lowest computation the work of the institute since its incorporation, if measured in dollars and cents alone, would represent a capitalization of over $34,000,000. This represents merely a capitalization of the increased earning power of our graduates and takes no account of the enterprises which they have developed and which they direct, which would easily make the pecuniary measure of the contribution of our graduates to the world's assets a sum not less than $50,000,000.

Let us see if on this basis the state, the county and the city have not been great gainers by reason of the work of this institution.

The commonwealth from the earliest time has aided the cause of education, but has now withdrawn pecuniary aid from all the higher institutions of learning excepting from the three schools within her borders which are occupied with the problem of technical education, namely, the Massachusetts Institute of Technology, the Agricultural College at Amherst and the Polytechnic Institute at Worcester. To this school the commonwealth has given the sum of $200,000 in cash and makes an annual payment of $10,000 in consideration of which the institute educates 40 students who pay no tuition, at an expense to the institute of over $12,000 annually. But this by no means measures the benefit conferred by the school upon the state.

There are now engaged in active life in this commonwealth 397 of our graduates which represents directly and indirectly a wealth-creating power represented by a capitalization of approximately $20,000,000, against which may be set the $225,000 which has been received from the commonwealth during the period, making the balance against the commonwealth a considerable one. There are now engaged in active life in this county 214 of our graduates who represent directly and indirectly a wealth-creating power represented by a capitalization of $10,000,000. Certainly Mr. Boynton's gift of $100,000 for the benefit of the youth of Worcester County has borne fruit at least an hundred fold. There are now engaged in active life in the city of Worcester 173 of our graduates, representing upon the basis we have adopted a capitalization of $8,750,000.

Including the recent gift and bequest of Mr. Salisbury, the value of all our property, real and personal, is in round numbers $1,300,000, of which $1,000,000 has been contributed by citizens of Worcester. What a rich return upon the investment!

In addition to this, the institute, at an annual expense of about $300 per student, is educating at the present time over 100 Worcester boys a year, for which is paid the regular tuition of $160 per year, which equals but little more than one half of the cost, so that the institute is contributing to the youth of the city educational advantages which cost it $15,000 annually. Is there not abundant reason for the belief that when the need arises the citizens of Worcester will contribute generously to the funds of the institute?

Worcester is peculiarly dependent upon the brains of her people for her prosperity, much of which is due to our technically trained men who are directing the industrial affairs of the city, and upon whom the city must largely depend for future prosperity. Such in brief is the debt of the state, the county and the city to the school.

Since its organization something over two thousand students have been members of the institute. Eliminating from consideration all who did not graduate, the cost

to the institute of educating the 1,095 students who graduated has been $1,037,834, and there has been received from these students in the form of tuition fees the sum of $273,483. In other words the cost of education of the graduates has exceeded by $764,351 the amount received from them. In this computation no account is taken of the investment in plant and equipment which would increase the amount by about $400,000. In good time, I doubt not, the alumni who are able to do so will be glad to treat this as an obligation which they will take pleasure in discharging, though the facts are not mentioned here for the purpose of unduly emphasizing what might perhaps be regarded as a disquieting suggestion.

The application of science to the useful arts has had a controlling influence upon the political as well as the economic history of the world.

In 1814 Mr. Calhoun favored double duties as a protective measure. Mr. Webster, then senator from Massachusetts, opposed this policy. How strange his words sound to-day:

> I am not in haste to see Sheffields and Birminghams in America. I am not anxious to accelerate the approach of the period when the great mass of American labor shall not find its employment in the field.

In 1828, when a large investment had been made in manufacturing industries in Massachusetts, Mr. Webster had changed his position and favored the tariff. But the tariff was resisted by South Carolina, and the legislature of that state put forth the famous 'exposition and protest' containing Mr. Calhoun's doctrine of nullification. Thus was the position of these great men entirely reversed upon the question of the tariff. The explanation is very simple.

In 1791 our cotton was all imported, and the south wanted a duty to encourage its domestic production. The invention of the cotton gin by Eli Whitney, in 1793, a Worcester County boy, already referred to, which made it easy to separate the green cotton seed from the staple, revolutionized the cotton industry and made the south independent of the tariff. The invention of the cotton gin compelled the enunciation of the doctrine of nullification. The doctrine of nullification compelled the civil war.

Knowledge of engineering makes possible such great works as the building of the Suez Canal, which has revolutionized the trade relations between Europe and the east; the building of the great dam at Assouan to store the surplus water of the Nile; the construction now fairly beginning of the Panama Canal.

Another striking illustration is found in the policy adopted by the national government in the act of Congress of June 17, 1902, appropriating the receipts from the sale and disposal of public lands in certain states and territories to the construction of irrigation works for the reclamation of arid lands which cover about two fifths of the area of the United States. This fund now amounts to about $30,000,000, and projects under consideration in fourteen states contemplate the irrigation of 1,441,000 acres of land at an average cost of $25 per acre. A single example may be found in the work now under way in Wyoming in the portion of the Big Horn basin on the north side of the Shoshone River seventy-five miles east of Yellowstone Park.

This involves the construction of a dam seventy-five feet wide at the bottom of the channel and 200 feet wide at an elevation of 240 feet, the proposed height of the dam above the river bed, and the building of a spill-way connecting with a tunnel through the solid granite of the mountain. The canyon is so narrow that it is regarded as feasible to enclose the entire area covered

by the dam so that the enclosure may be heated and the work carried on during the winter. It is anticipated that 175,000 acres of land will thus be reclaimed, and that a population of 50,000 people will be added to a community now thinly settled. This great work, primarily of the civil engineer, is contributed to by almost all departments of applied science. Suitable foundations for the dam must first be found. The mechanical engineer explores with his drills; the geologist and the chemist determine the character of soil and rock; the civil engineer plans and constructs; the electrical engineer takes power developed from storage reservoirs and transmits it electrically to pumping areas and installs a telephone service so that the system may be safely and efficiently administered.

The once naked savage, who, perhaps, almost dying of hunger and thirst, feebly directed his tottering steps over these lonely and unfruitful regions, now at daily wages, which ensure him every comfort, participates as a citizen of the United States in this beneficent undertaking. In place of desolation will be found a large and intelligent population busily engaged in agricultural pursuits and all the attendant industries, while the church, the school, the college—companions of the highest type of civilization—create and minister to the noblest aspirations of a prosperous community. Thus does applied science contribute to the advancement of mankind.

One most potent influence in our industrial development has been our system of patent law. The patent office was created by the act of 1836. Up to January, 1861, 31,000 patents had been issued. Up to January, 1906, something more than 800,000. Under the stimulus of these laws the inventive faculty of our people has exceeded that of any other country. In the administration of these laws within the patent office and in the practise under them without, there are now engaged more than thirty of our own graduates who are peculiarly fitted because of their training to succeed in this important field.

The industrial development of the world has been stimulated by the great expositions which have been held from time to time in different countries. That of England in 1851; at New York in 1853; at Paris in 1855; again in England in 1862; in Paris in 1867, greatest of all up to that time; at Vienna in 1873; at Philadelphia in 1876; at Paris in 1878; at Chicago in 1893; and at St. Louis in 1904.

I have recently seen the statement that modern technical education is the direct result of the London exhibition of 1851, where for the first time was given an opportunity to see side by side the industrial products of all nations. However this may be, it is certainly true that the event was one of great importance to the industrial world.

In February, 1850, the first of the great public meetings on the subject was held in England. France, Prussia, America and Belgium were represented. Lord Morpeth, who presided at the meeting, in closing his speech, said:

> I can not better sum all that may be said than in words written nearly a century and a half ago. Listen, ladies and gentlemen, and see if Pope was not almost as good a prophet as he was a poet:
>
> The time shall come, when, free as seas or wind,
> Unbounded Thames shall flow for all mankind,
> Whole nations enter with each swelling tide
> And seas but join the regions they divide;
> Earth's distant ends our glories shall behold
> And the new world launch forth to seek the old.

The Prince Consort, to whom the chief credit is due for the inception and management of the great enterprise, made a speech at the Mansion House in March, 1850, in which he said of the purpose of the exhibition that it was to

give the world a true test, a living picture, of the point of individual development at which the whole of mankind has arrived, and a new starting point from which all nations will be able to direct their future exertions.

How well it served its purpose is demonstrated by the fact that at the exposition in Paris in 1867 England found that while in 1851 her supremacy had been undisputed, in 1867 out of 90 departments she had superiority in only 10. An investigation led to the conclusion that the cause of this was the better scientific instruction given to artisans on the Continent. France, Prussia, Austria, Belgium and Switzerland possessed good systems of industrial education for the masters and managers of factories and workshops, while England possessed none.

An Englishman, a judge in the class of woolen textile fabrics, said, speaking of the continental workmen:

Brains sit at the loom and intelligence stands at the spinning wheel.

At this exposition the progress of France and Germany was especially commented upon.

Sir Lyon Playfair, speaking some years ago of the influence of technical education upon the industrial prosperity of Switzerland, said:

The Coventry ribbon trade, which has deserted England, has settled in the valleys of Switzerland. The polytechnic institute has aided in this result, because it turns out seventy or more persons annually, trained in the science and art requisite to conduct such a manufacture successfully.

This single branch of manufacture so transferred from England to Switzerland employs in the latter thirty thousand weavers and other collateral workers, such as dyers and superintendents. The value of the annual export of this manufacture from Switzerland is eight million dollars, while the trade has languished at Coventry in England until the annual export is little more than three hundred thousand dollars.

"The difference," says Lord Lyon, between the Swiss trade and the Coventry trade, "is very simple; it is involved in the answer given by Opie, the painter, to a youth who asked him how he mixed his colors—'I mix them with my brains, sir.'"

It is a striking fact that England, which has produced Arkwright, Watt, Stephenson and Bessemer and others equally distinguished, should have been unable to keep pace with other nations in the application and development of the principles which these men first disclosed. It may be accounted for in some degree at least by another surprising fact, that in industrial education England is excelled by all the leading nations of the world.

There is undoubtedly a demand in this country at the present time for the education of those in our industries who need the skill of the mechanic and an order of intelligence superior to that of the ordinary workman. This has long been recognized and has been met in some slight degree both within and without this commonwealth. This need is more apparent than ever at the present time when the specialization of industries has reached a point where the old-fashioned all-around mechanic is becoming more and more difficult to find.

While there is no great dearth of engineers, there is a short supply of skilled workmen of intelligence. This is a department of industrial education that can not be safely neglected. Germany has appreciated this fact, and leads all the countries of the world in this as in all other departments of technical education, and owes to this, very largely, her present industrial position.

President Alderson, of the Colorado School of Mines, in a recent article, speaks as follows of present conditions:

There are six building and mechanical trade schools in New York and Brooklyn, three in Boston, two in San Francisco, and two in Philadelphia. New York has two brewing academies; Chicago and Milwaukee one each. Philadelphia, Lowell, New Bedford and Atlanta have textile

schools. Chicago, St. Louis, Omaha, Peoria, Waltham, Winona and LaPorte have watch making and engravers' schools. The universities of Wisconsin and Minnesota, and the Iowa College of Agriculture have schools of dairying. For dressmaking, millinery and the domestic arts and science, schools exist in Boston, New York, Brooklyn, St. Louis and Philadelphia. Eight cities contain schools to teach barbering. St. Louis has a school for railway telegraphers; Effingham, Illinois, a college of photography, and New York an academy for shipbuilders.

Still another extension of technical education is to be noticed in our large cities, where technical schools have opened their doors in the evening and have invited students, employed during the day, to enter and learn what they can. These night schools are exceedingly common in England, so common that they have undermined the influence of the regular day schools and have implanted the erroneous idea in the mind of the average young Englishman that he can work all day, go to school at night, and still be successful in each case. Such we know to be fallacious. The true conception of night school work is that it is only a means of securing essential facts, but is not education in its truest sense. The Germans have not made this mistake and emphasize the necessity of giving undivided attention either to educational work or to industrial work, but not to combine the two. Interesting in connection with evening instruction by technical schools is the use of local centers or technical clubs, with home-rule organization, but with the same end in view.

At the end of this list must be added the educational work of the Y. M. C. A., which quietly but effectually reaches thousands of students. All these influences combined reach an industrial army that can be counted in the millions. The movement for more technical education is certainly far-reaching and important.

He also expresses the opinion that at one time or another not less than two million in the United States have taken one or more courses in some correspondence school. The industrial training given at Tuskegee is another indication of the great value placed upon it as an essential part of education and possesses additional interest and importance from the fact that it is regarded as the most efficient manner in which to permanently improve the condition of the negro in the south.

In our own state, the Lowell Textile School opened in October, 1897; that in New Bedford in October, 1899, and that in Fall River in 1900. These, in Massachusetts, are trade schools of a pure type, and serving a most useful purpose, supported in part by the commonwealth in the interests of the textile industries which from the earliest times have been so important to our people.

This need was recognized by the advisory committee invited by the trustees of the Carnegie gift to present a plan for the technical school to be established at Pittsburg. They recommended the establishment of the (1) Carnegie Technical College; (2) Carnegie Technical High School, where is to be taught engineering principles, steam engine practise, pattern making, tool making, etc.; (3) Carnegie day and evening classes for artisans. The two latter recommendations attempt to provide for the need of which I have spoken. This plan seems to be modeled upon that of Norway, proposed in 1868, involving Sunday and evening schools for mechanics, elementary technical schools of a practical character and a polytechnic institute of the highest grade.

The subject of industrial and technical education in this commonwealth has been recently considered in the report of a committee appointed under the authority of the legislature of which our accomplished fellow townsman, Dr. Carroll D. Wright, president of Clark College, is the chairman. His attainments in industrial economics make this report of authoritative value. In it the need in this country is recognized of more skilled workmen, of those possessing not so much manual dexterity as 'industrial intelligence,' by which is meant—and I now quote from the report—

Mental power to see beyond the task which occupies the hands for the moment to the operations which have preceded and to those which will follow it—power to take in the whole process, knowledge of materials, ideas of cost, ideas of organization, business sense, and a conscience which recognizes obligations.

This need the committee believes should be met by industrial education in the public schools and through independent industrial schools; such instruction is, of course, designed for students younger than those with whom we have to deal here, and is of an entirely different grade and character, but, nevertheless, is of very great importance. In this report the Massachusetts Institute and the Worcester Polytechnic are spoken of as institutions which train mechanical and electrical engineers, manufacturing chemists and architects—men in the highest ranks of productive industrial life; institutions which have fully justified all that they have cost and of world-wide fame.

If I may borrow further from this interesting report, I will add that the system of industrial and technical education in the German empire is held up as an example, and a comparison is made which shows that if Massachusetts were to maintain a system of industrial schools of proportionate development with that of the kingdom of Prussia, we should need three hundred such schools with a total enrollment of twenty thousand.

It would be idle to assert that the industrial supremacy of the United States is due primarily to our system of industrial education, because, as a matter of fact, we are inferior in this respect at least to Germany, France and Switzerland. But the time is certainly fast approaching when we must take heed of the industrial competition from other countries which are adopting our machinery and methods, stimulated by what they learn at the great expositions. It is certain that without great effort we can not retain our supremacy undisputed; and for this reason it behooves us to pay particular attention to the industrial education of our people.

Just as in agriculture, after the virgin soil begins to be exhausted by wasteful methods of cultivation, scientific methods must be employed if the quantity and quality of crops are to be maintained; so in other industrial pursuits—as competition forces prices down, the labor must be more intelligent, the scientific knowledge more exact, if satisfactory results are to be secured.

It is a mistake to think, as is often said in this country, that the 'pauper labor' of Europe is a menace to us. It is rather the educated labor of European competitors of which we should stand in fear.

I believe it to be true to-day that in a large number of our industries in which labor-saving machinery is used to any considerable extent, the cost of labor per unit is less than in any country in the world, and for the reason that our labor is so much more efficient.

As men with a technical education are the ones who will manage our railways and great manufacturing plants, they naturally have a deep interest in, and should have an intelligent knowledge of, the changing conditions under which business is being done, information which our own students acquire in the department of political science.

The factory system was a product of the close of the eighteenth century—the trust, so-called, of the close of the nineteenth; and great abuses have attended each change, which are quite independent and separable from the system which they accompanied.

The great cruelties attendant upon the labor of women and children were a blot upon the former. These have happily largely disappeared before the corrective

of intelligent legislation—and the same remedy will no doubt be efficiently applied in due time to the evils attendant upon the latter, to which the attention of the whole country is now directed.

To consolidation as such, I think there can be no rational objection, and I will hazard the opinion that competent young men who are obliged to stand absolutely on their own merits have a better chance to succeed to-day than ever before in the history of the country. The time at my command—already, I fear, exhausted, as well as your patience—does not admit here of any extended discussion of this interesting question.

The 'good old times' were not as good as these, and I believe that these are not as good as those that are to come. Macaulay, who so richly embellishes every subject he touches, uses the following illustration:

> In truth, we are under a deception similar to that which misleads the traveler in the Arabian desert. Beneath the caravan all is dry and bare; but far in advance and far in the rear is the semblance of refreshing waters. The pilgrims hasten forward, and find nothing but sand where, an hour before, they had seen a lake; they turn their eyes, and see a lake where, an hour before, they were toiling through sand. A similar illusion seems to haunt nations through every stage of the long progress from poverty and barbarism to the highest degrees of opulence and civilization. But, if we resolutely chase the mirage backward, we shall find it recede before us into the regions of fabulous antiquity.

At no time has the question of the rights of the people, as against those of the so-called vested interests, been as prominent, I may say as all-absorbing, as at this moment. Forty years ago the government was encouraging the building of railroads by enormous grants of land. The chief desire of the nation and the states was to get the means of transportation at any cost. The recent session of Congress has been largely devoted to devising means for regulating railroad rates—already at a lower point than any one twenty years ago would have dared to predict. I have no quarrel with this wholesome legislation. I merely use the incident as an illustration. This is the day of the reasonable control of business and of the elimination of abuses which have inevitably sprung up alongside and been dwarfed by an industrial development more rapid and more stupendous than any that the world has ever seen. In this important work, educated men and, above all, technically educated men, should take the lead, if it is to be well done, and done it will be. The conscience of the country has been quickened as never before, largely, I believe, through the initiative of the president of the United States, who only needs to see a wrong to exert all the prerogatives of his great office to remedy it.

Happy that land where the people govern; where education is not for the cloistered few but within the reach of every child; where the limits to ambition are only those prescribed by the ability and disposition of the individual, and which advances from generation to generation to better and better things.

Charles G. Washburn.

SCIENTIFIC BOOKS.

The Biology of the Frog. By Samuel J. Holmes, Ph.D., Assistant Professor of Zoology in the University of Wisconsin. New York, The Macmillan Co. 1906. $1.60 net.

A most useful addition to our text-books on the frog. It presents not only the anatomy and embryology but also the physiology and natural history of the frog; so that for the first time a single book covering the whole ground of the biology of the frog is accessible to teacher and student.

The text of 358 pages is divided into nineteen chapters. The first places the particular kind of frog (the leopard frog, *Rana pipiens*), which is the chief subject of the volume, in proper relation to other kinds of frogs and to the salamanders by a brief consideration of